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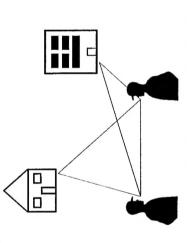
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DARPA

Wireless

Propagation Measurements, Analysis, and Modeling



SSC-SD D855

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DARPA



- Measurement Goals and Capabilities
- Multipath Tutorial
- Sample Results
- Urban Channel
- HMMWW Motion
- Human Mount w/Motion
- Various Antenna Heights
- Many Channels
- Path Loss vs. Delay Spread
- Model Comparisons







Urban/Suburban, Hills/Trees, Airfield

Antennas close to buildings

Antennas mounted on humans in motion

- Low antenna heights

- VHF, UHF, ISM, LBand

Compare w/existing Propagation Models





Measurement System Capabilities

- Long Duration (25s)
- High Resolution (12m)
- Long Range (10km)
- Frequency Versatile (30MHz-2GHz)
- Severe Environments (Heavy Urban)
- Arbitrary Waveform Capability



Data Applications



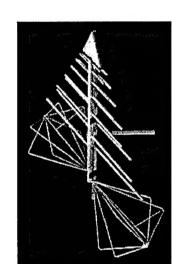
- Propagation Science
- Radio Design
- Algorithm development/testing
- Waveform development/testing
- Antenna development/testing
- Transmit power selection/power control design
- Frequency and BW selection
- Computation update requirements
- Network Modeling
- Network Design

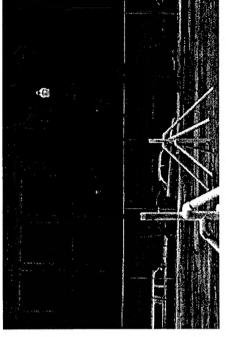


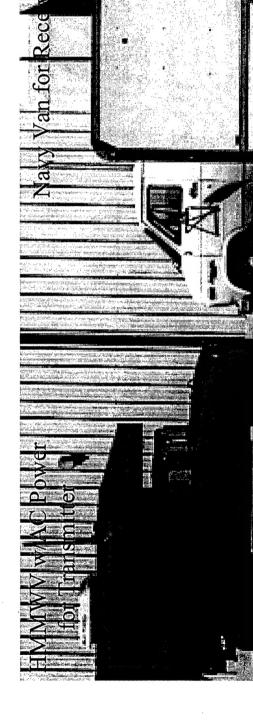


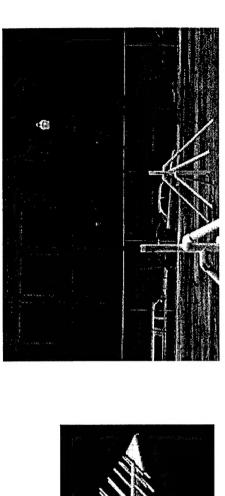
Transmitter/Receiver Antennas Receiver Antennas

Transmitter Antennas







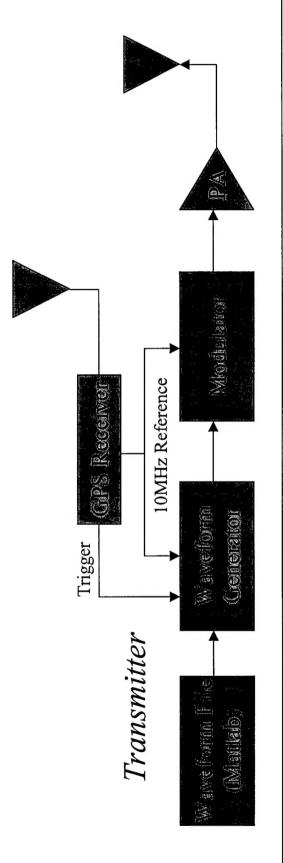


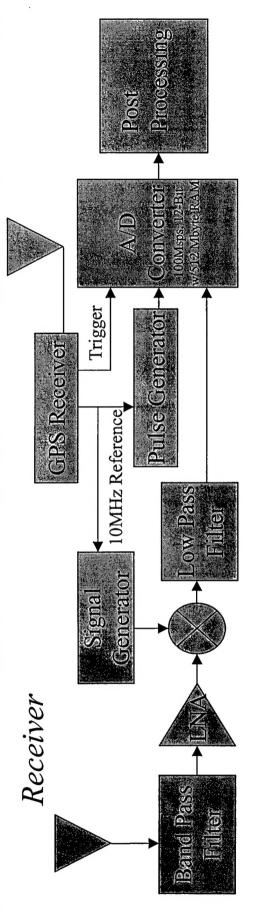


Propagation Testbed



30MHz-2GHz



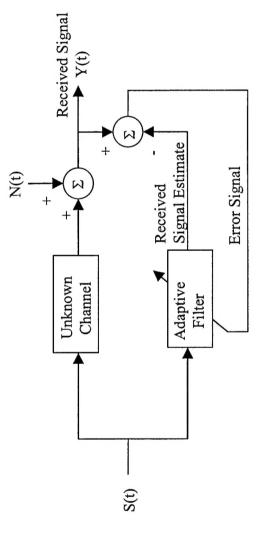




Adaptive Channel Estimation

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- Adaptive FIR Channel Estimation Filter:
- 3 Phases:
- · Acquisition Recursive Least Squares (RLS)
- Training Normalized Gradient Decent (NLMS)
- Tracking Normalized Gradient Decent (NLMS)
- Filter Tap Length 240 Taps





DARPA



» Multipath Tutorial

Sample Results

Urban Channel

HMMWW Motion

• Human Mount w/Motion

· Various Antenna Heights

Many Channels

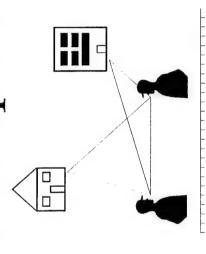
• Path Loss vs. Delay Spread

Model Comparisons





Multipath



Exact solution: Maxwell's equations and Boundary Conditions

Approximate solution: Trace rays using geometric optic rules

Better: Add edge diffraction and transmission through wall

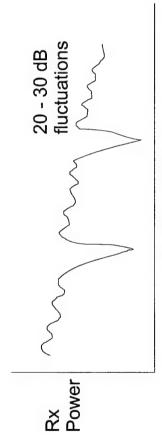
But: Need a good geometrical description of the environment

Alternative: STATISTICAL DESCRIPTION



Narrowband Signals

$$p_{\tau} = p_o \left| \sum_{i=1}^{L} \frac{a_i}{d_i} e^{j \varphi_i} \right|^2$$



Tx - Rx Distance





Wideband Signal

$$h(\tau,t) = \sum_{i=1}^{L} \beta_i e^{j\varphi \delta(t-\tau_i)}$$

$$y(t) = \int x(t-\tau') h(\tau,\tau'')$$

$$= \int x(t-\tau') \sum_{i=1}^{L} \beta_i e^{j\varphi_i} \delta(\tau'-\tau_i) d\tau'$$

$$= \sum_{i=1}^{L} \beta_i e^{j\varphi_i} x(t-\tau_i)$$







Ideal Case (Infinite BW)

Let
$$x(t) = \delta(t)$$

 $\Rightarrow y(t) = h(\tau, t)$
 $|y(t)|^2 = y(t)y^*(t)$
 $= \sum_{i=1}^L \sum_{k=1}^L \beta_i \beta_{ke^{j(t-\tau_i)}}^* \delta(t-\tau_k)$
 $p = \int |y(t)|^2 dt =$
 $= \sum_{i=1}^L \sum_{k=1}^L \beta_i \beta_k^* e^{j(\varphi-\varphi_k)} \int \delta(t-\tau_i) \delta(t-\tau_k) dt$
 $= \sum_{i=1}^L |\beta_i|^2$



Power Delay Profile (Practical Case)

JARPA

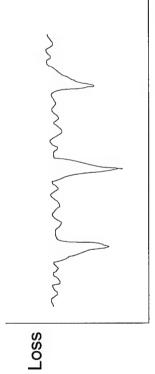


$$\sigma = delay \ spread$$

Smearing due to convolution.



Channel Frequency Response



frequency

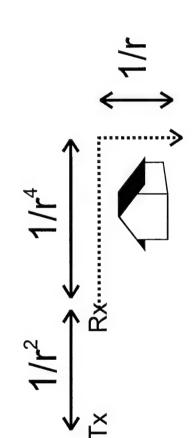




Modeling

DARPA

• Path Loss (JTC)

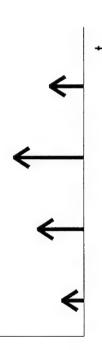




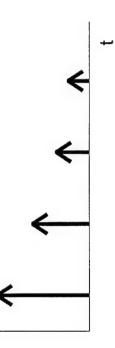


Canonical Tapped Delay Line Model

Urban High Rise



Urban Low Rise

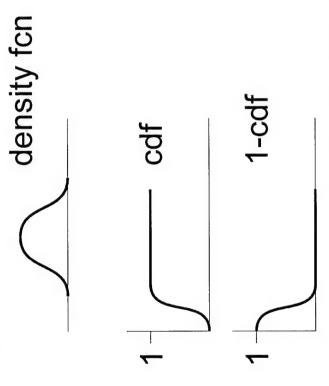






Motion Measurements (8 Sec)

A collection of channel realization in a single measurement



Loss on Delay Sprea





Motion Measurements (8 Sec)

Compute means and

1) Compare to each other

different carrier freqs

different environments

- 2) Compare to Models

• JTC

• Hata

TIREM



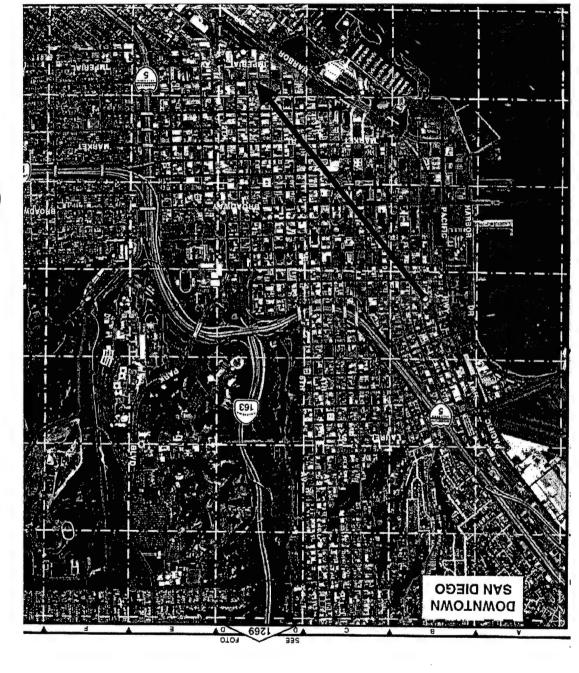




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Urban San Diego









Airfield and Urban Delay

Airfield

(3.48 km; 237 MHz)

-115

-135

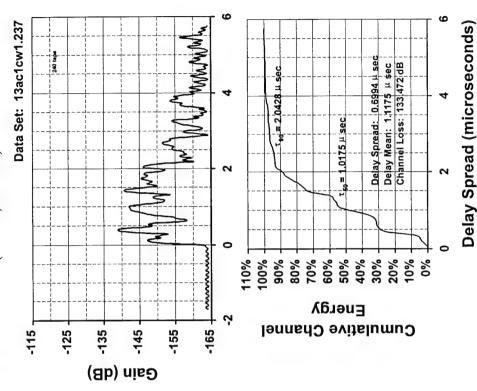
(ab) nise

-125

Data Set: 05ac1bw1.237

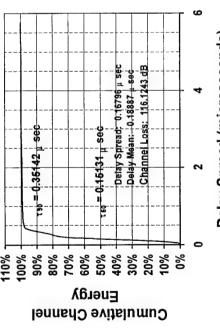
Profiles Urban

Urban (2.15 km; 237 MHz)



MYV

-155

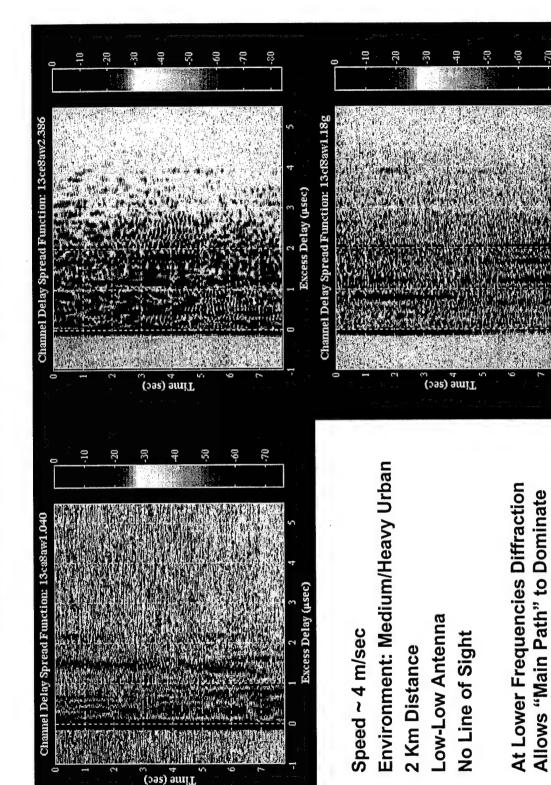


Delay Spread (microseconds)



Channel Estimates - Motion





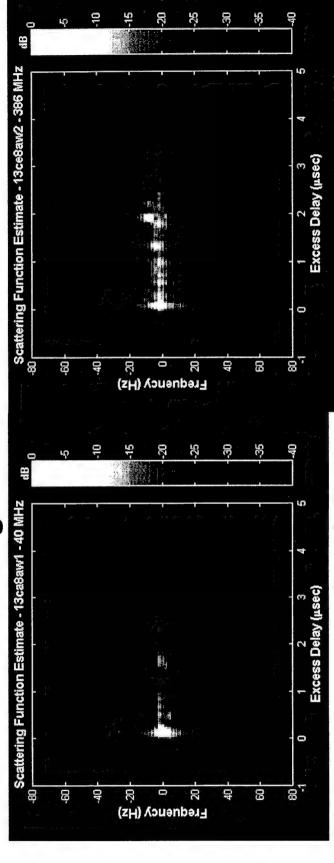
Higher Frequency Channel(s) tend to

exhibit greater energy delay



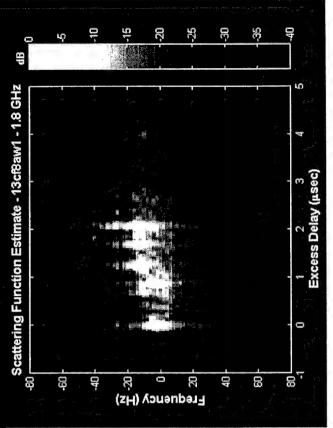








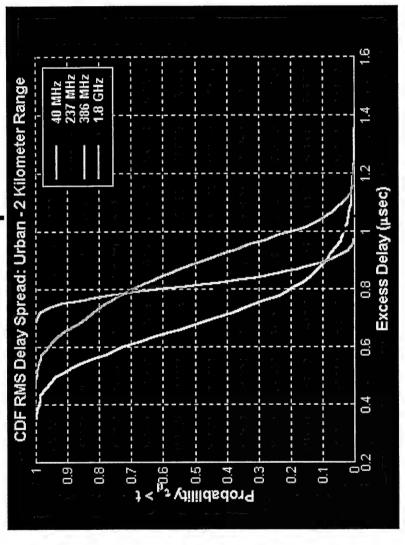
- Environment: Medium/Heavy Urban
- 2 Km Distance
- Low-Low Antenna
- No Line of Sight
- Lower Frequencies exhibit more Compact Scattering Functions
- Lack of Diffraction Limits Performance on Higher Frequency







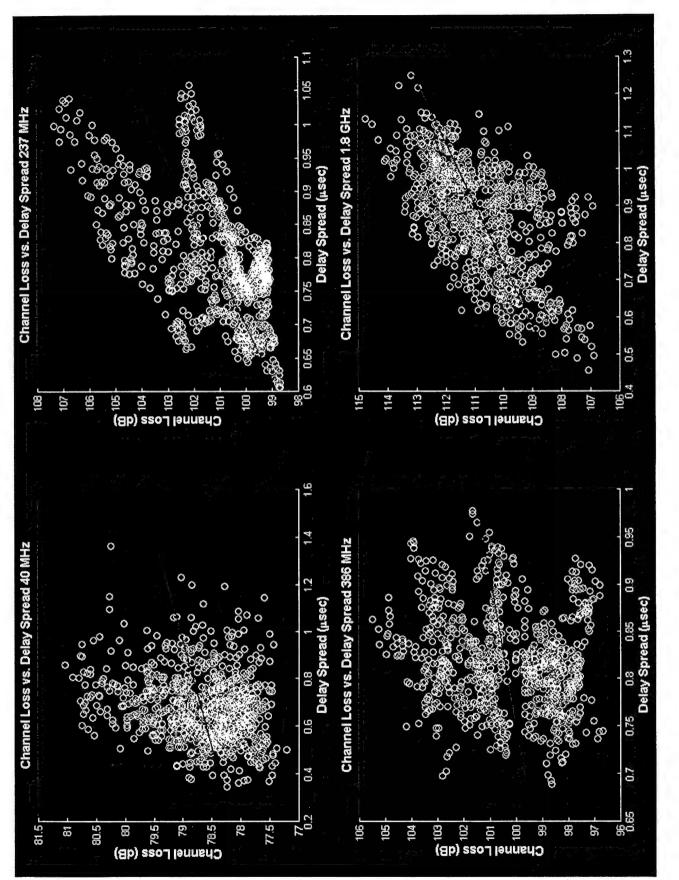
Channel Response



- ~320,000 Channel Estimates taken at 44 kHz
- Averaged to 100 Hz for Power Delay Profiles to Estimate Delay Spread (and Loss)



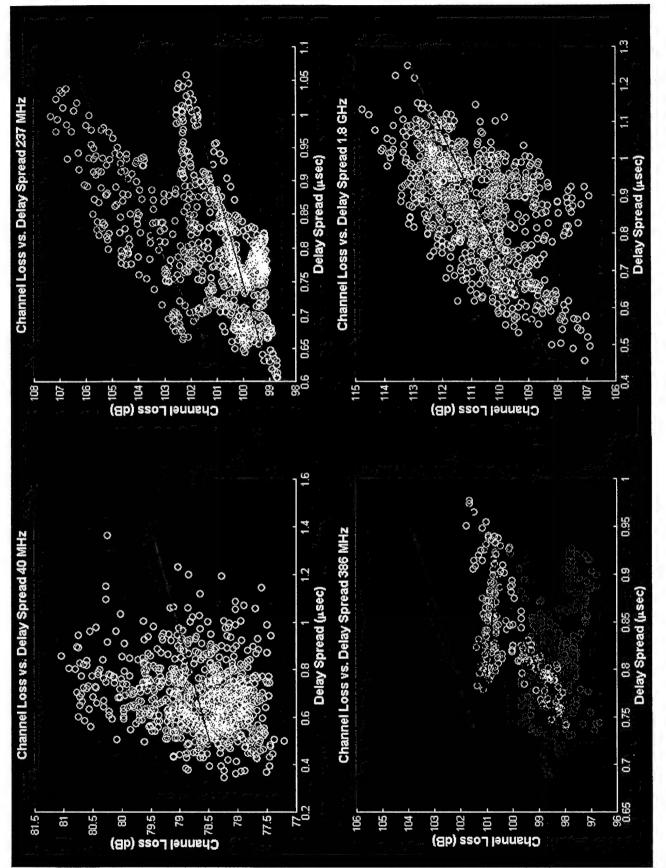
Channel Loss







Channel Loss

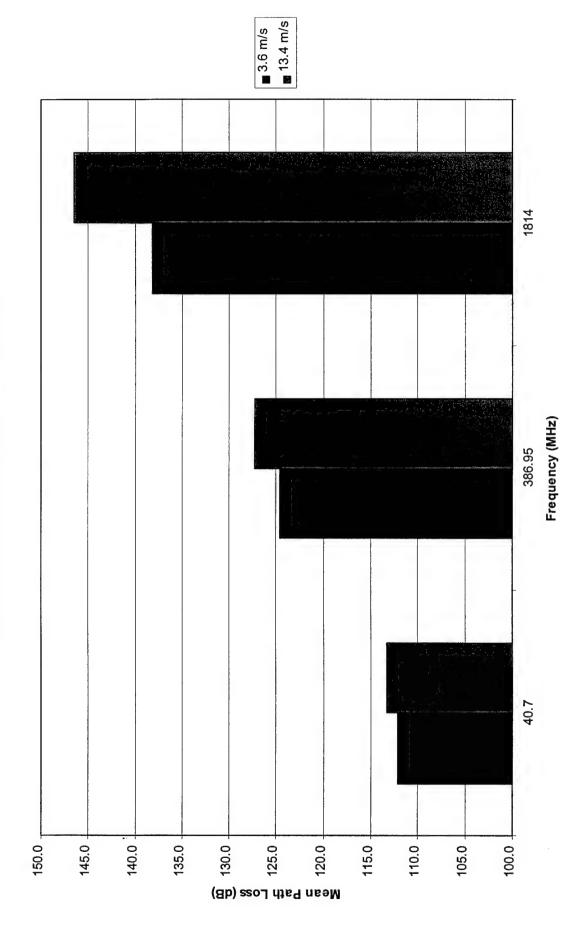








Urban Environment, (Ch. 13; HMMWV Motion)

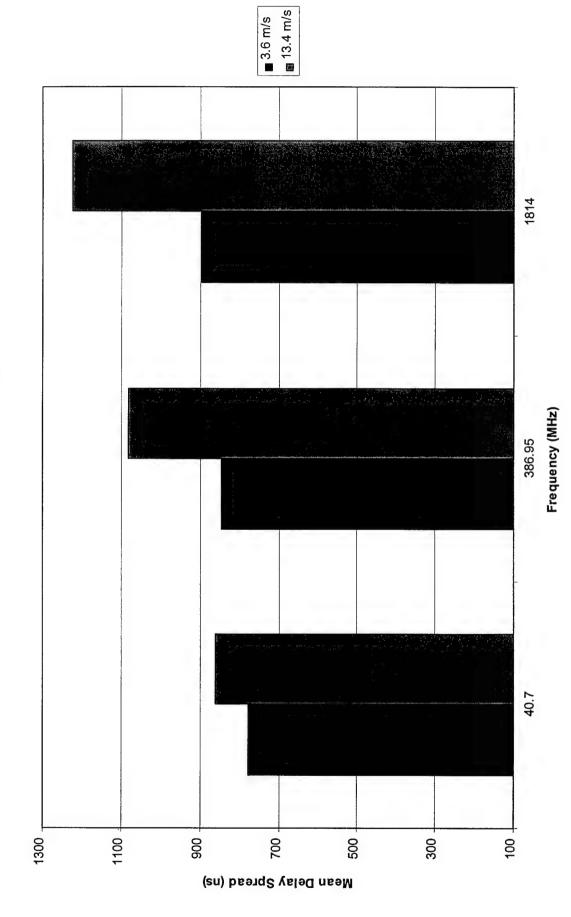






Urban Delay Spread

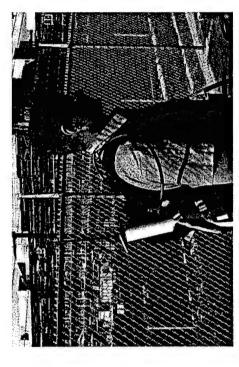
Urban Environment, (Ch. 13; HMMWV Motion)

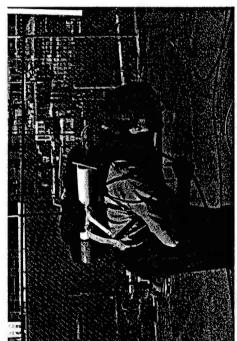


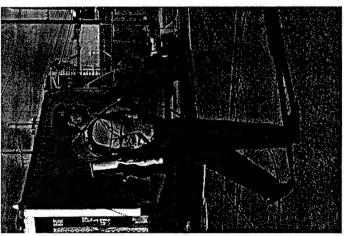


Soldier Mount





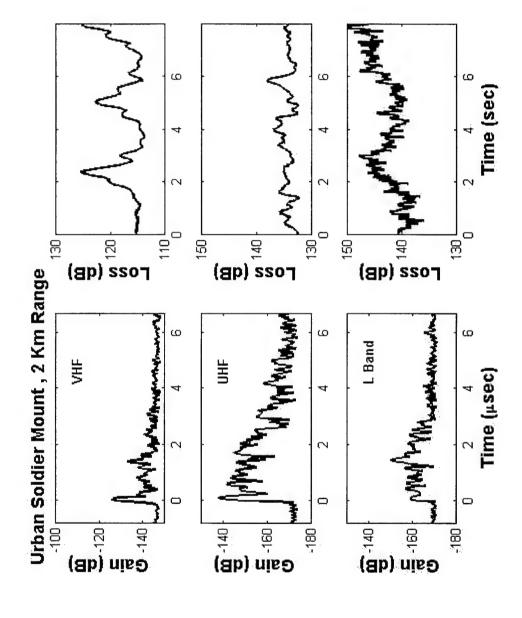








Soldier Mount

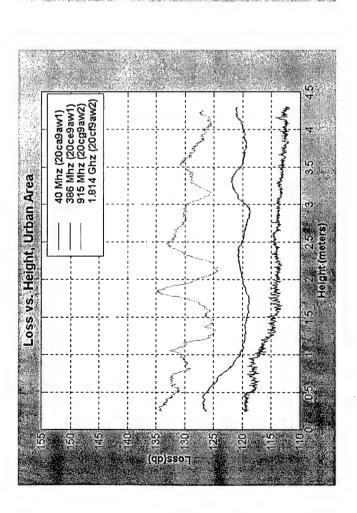


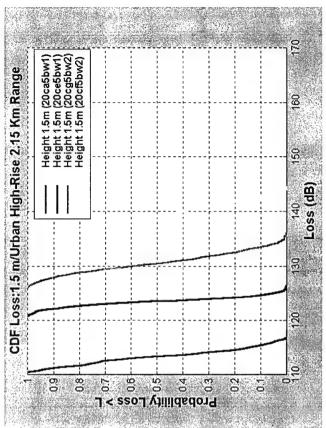






Urban Path Loss vs. Height

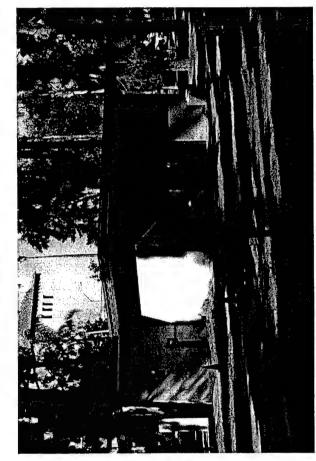






Balboa Park, Block Building











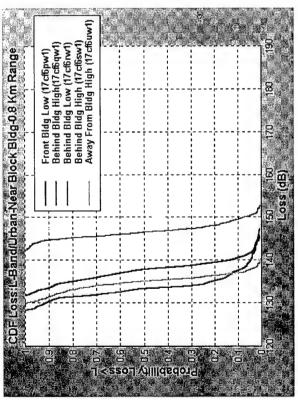
North Island - Metal Building

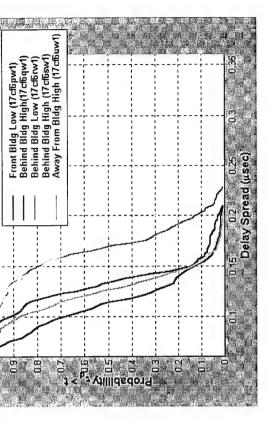


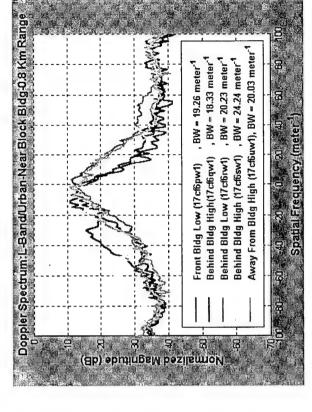


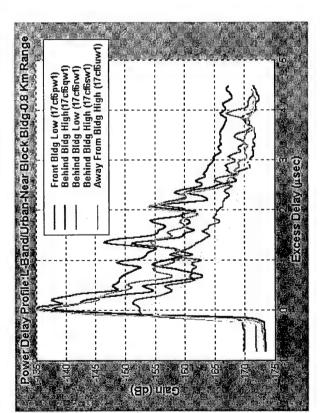


CDF RMS Delay Spread: L-Band/Urban-Near Block Bldg-0.8 Km Range



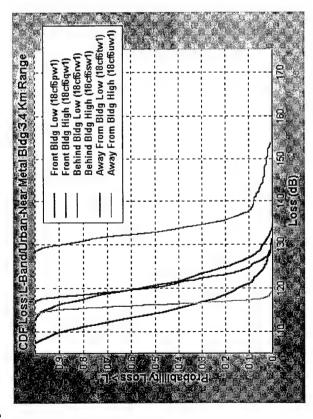


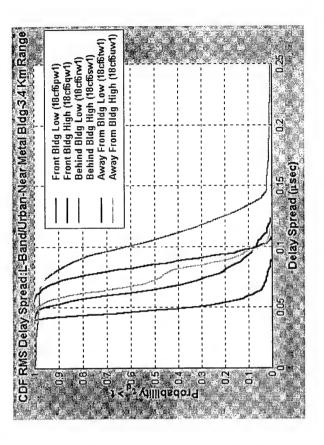


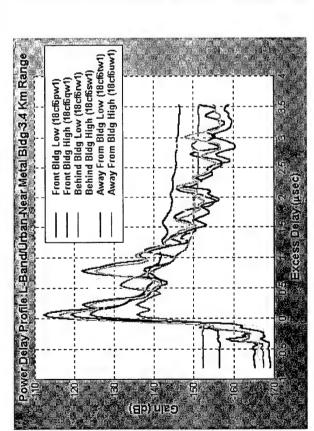


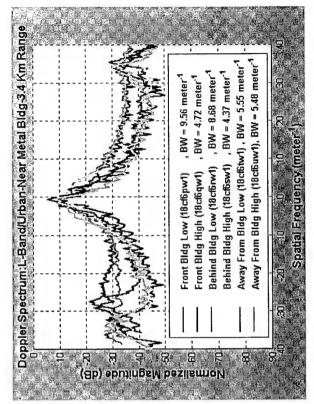






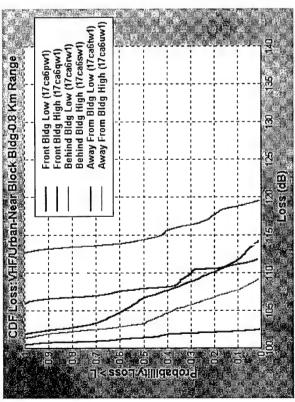


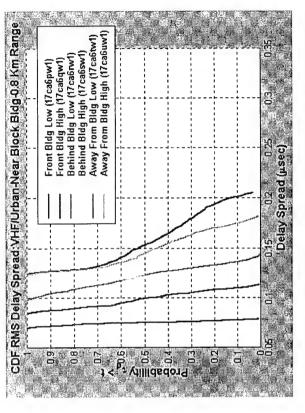


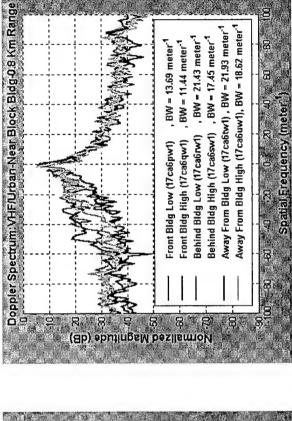


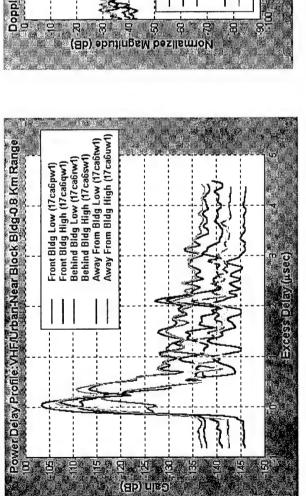






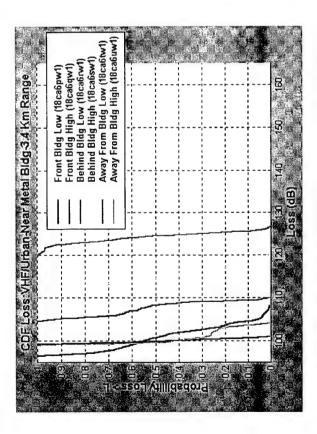


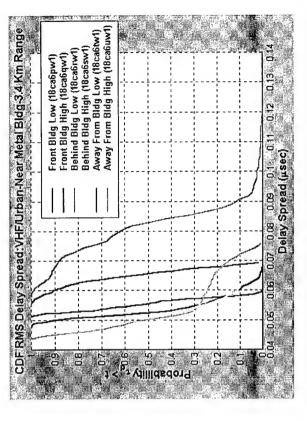


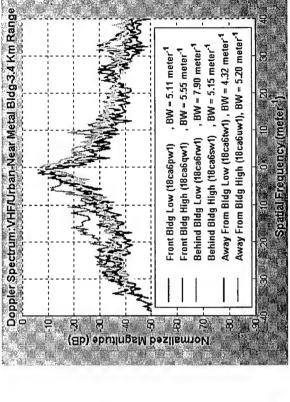


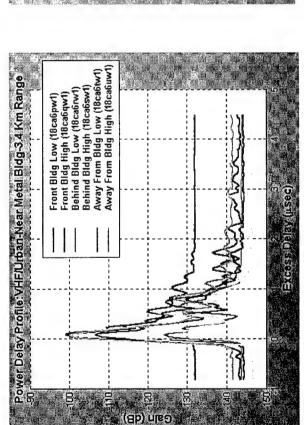








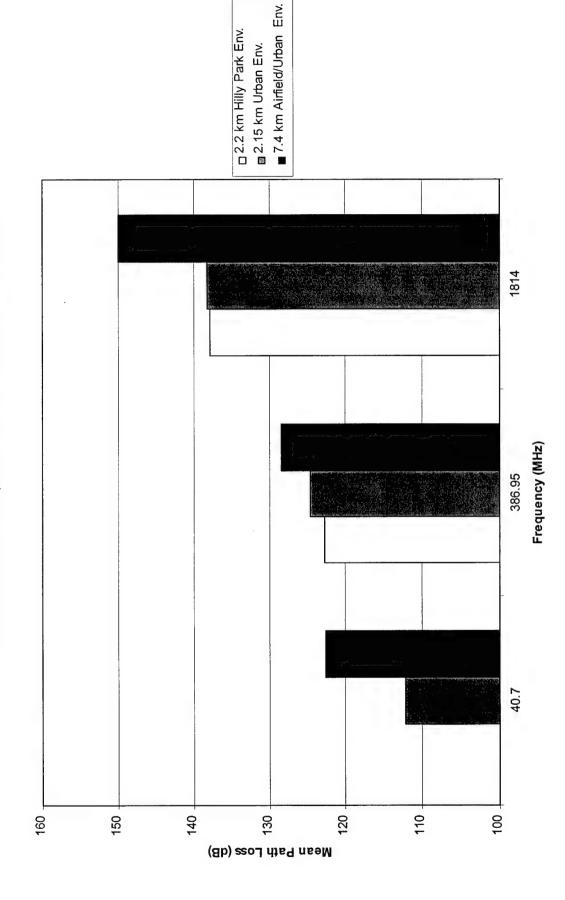






Path Loss vs.

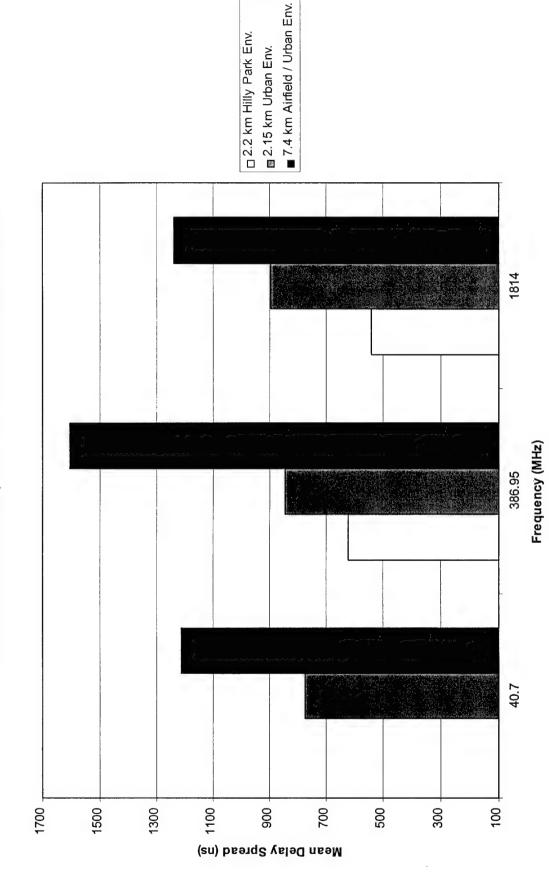
Frequency & Environment Various Environments (Ch 16, 13, 19; 3.6 m/s HMMWV Motion)





Delay Spread vs.

Frequency & Environment Various Environments (Ch 16, 13, 19; 3.6 m/s HMMWV Motion)

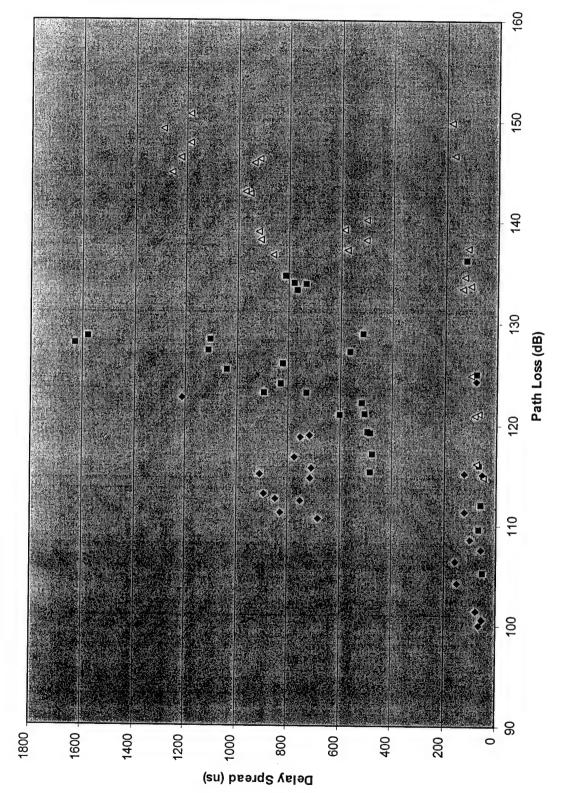




PL-DS Scatter Plot (All Cases Combined)

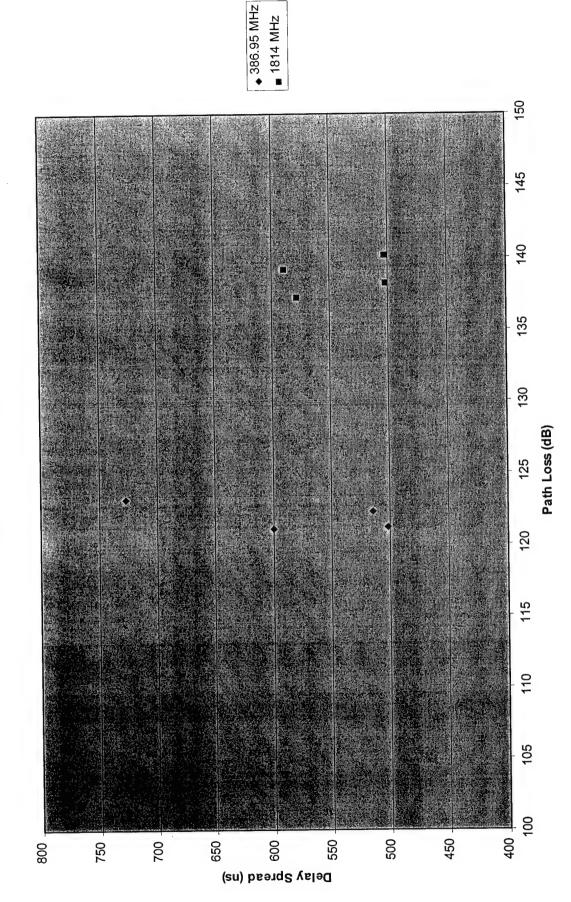


◆ 40.7 MHz ■ 386.95 MHz 1814 MHz



Balboa Park Hills/Trees (2.2 Km)

PL-DS Scatter Plot (Hilly Balboa Park, Ch.16)

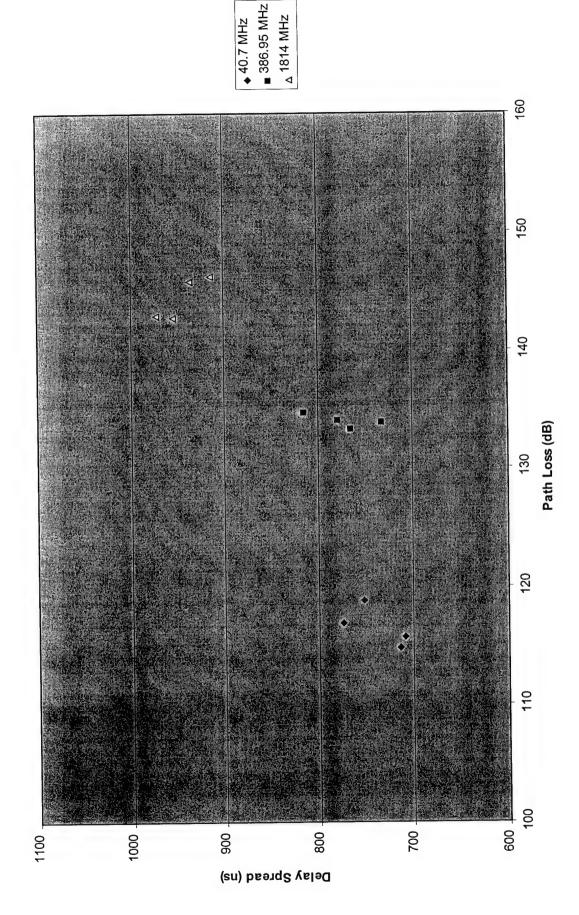






Urban Soldier Mount (2.1 Km)

PL - DS Scatter Plot (Soldier Motion, Ch. 13 & 20)

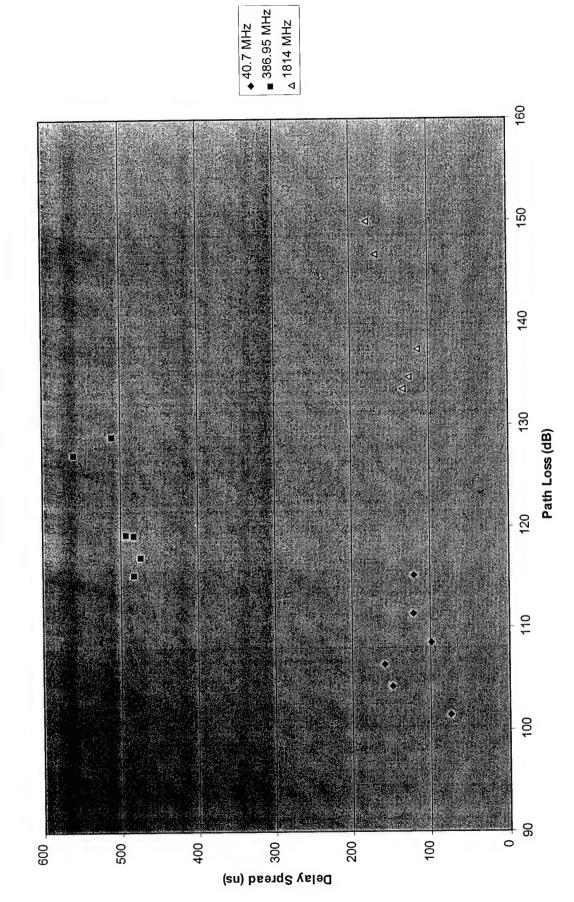






Balboa Park (0.8 Km)

PL - DS Scatter Plot (Block Bldg, Ch. 17)

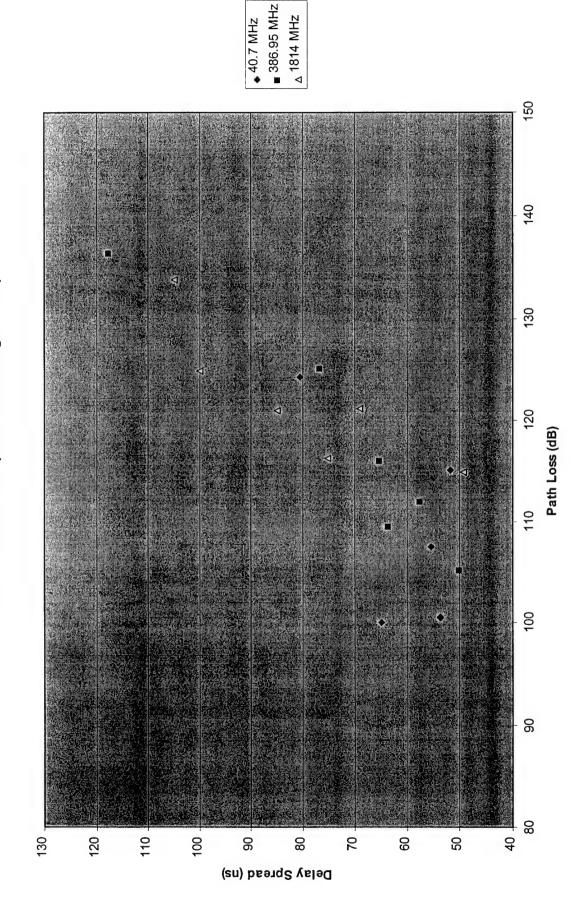






Airfield (3.4 Km)

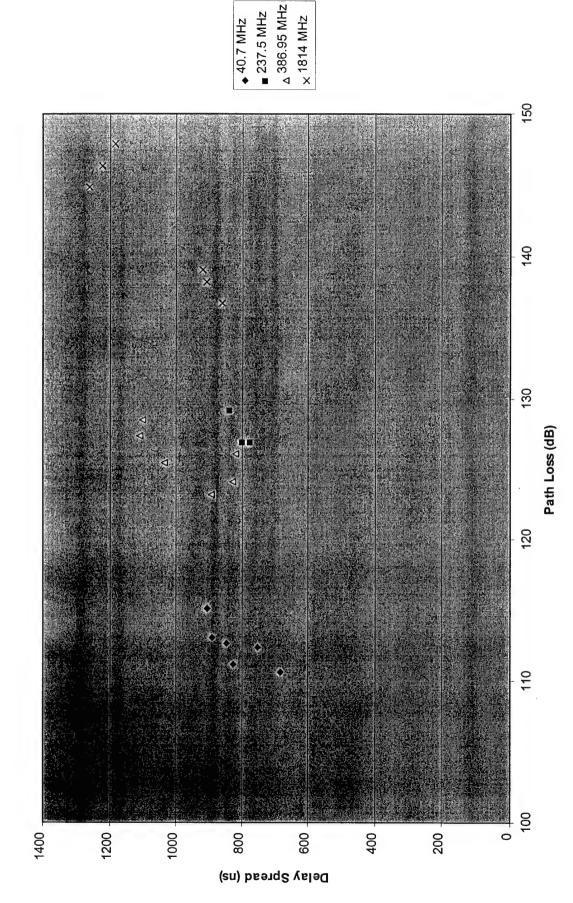
PL - DS Scatter Plot (Near Metal Bldg, Ch. 18)





Urban HMMWW Mount (2.1 Km)

PL - DS Scatter Plot (Urban, Ch. 13)





Outline

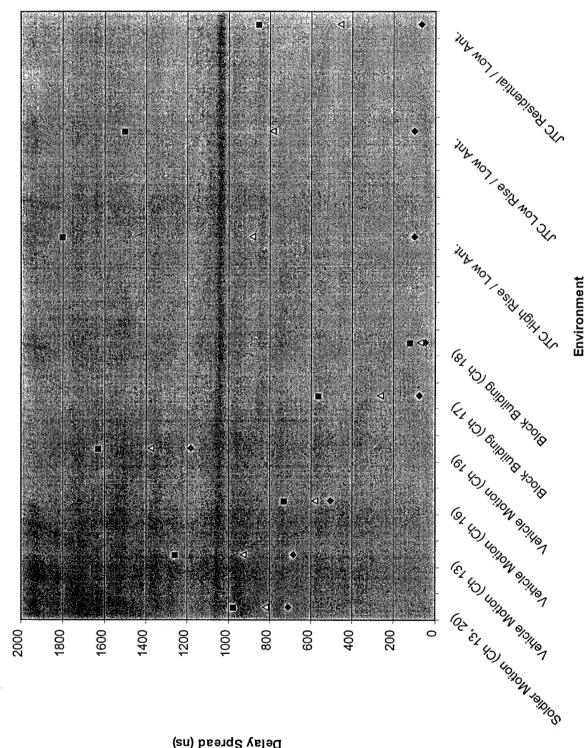


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JTC Model Comparison



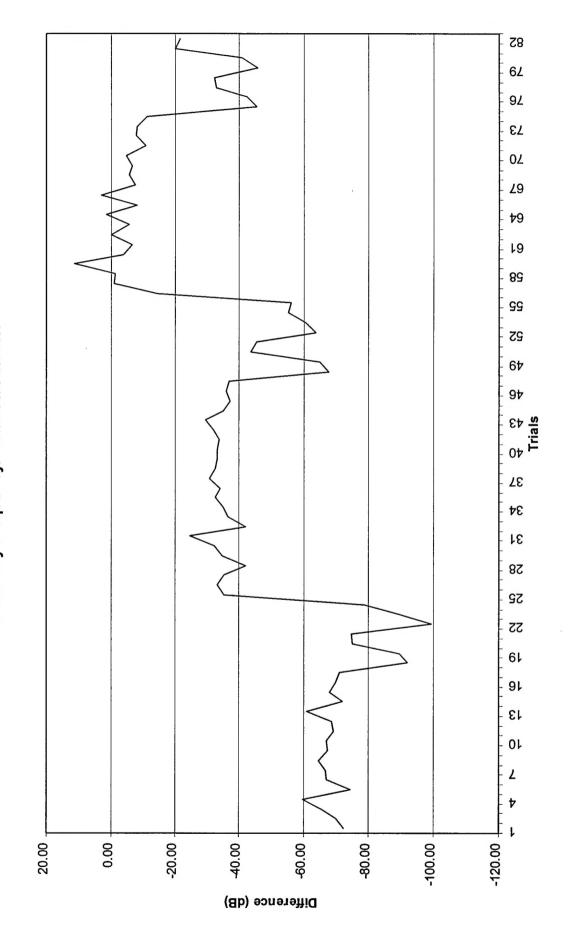


Average Values --- Max Values → Min Values

Delay Spread (ns)



JTC Model Comparison Measured - JTC (dB) Sorted by Frequency/Distance/Channel





Hata Model Comparison Measured - HATA (dB) Sorted by Frequency/Distance/Channel

